



Instruction Manual

Models 810B, 810BL, 810BB, and 810BS

WELL-TYPE
SCINTILLATION DETECTORS

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INSTRUCTION MANUAL

I. GENERAL DESCRIPTION

A. Summary of Model Differences

This manual describes four scintillation detectors which differ in type or size of crystal or size of well; their electronic circuitry is precisely the same.

- (1) Model 810B is a well-type, gamma ray scintillation detector with crystal scintillator, photomultiplier tube, and pre-amplifier with gain of 10. It counts test tube samples up to 5 ml in volume.
- (2) Model 810BL is a well-type gamma ray scintillation detector with crystal scintillator, photomultiplier tube, and pre-amplifier with gain of 10. It counts test tube samples up to 15 ml in volume.
- (3) Model 810BB is a well-type beta ray scintillation detector with plastic scintillator, photomultiplier tube, and pre-amplifier with gain of 10. It counts test tube samples of beta rays with energies in excess of 1 Mev.
- (4) Model 810BS is a solid-crystal, gamma ray scintillation detector with crystal scintillator, photomultiplier tube, and preamplifier with gain of 10.

NOTE

Since the crystal-photomultiplier assemblies in the above units are completely interchangeable, any one of these detectors may perform all of the above functions by substituting the appropriate scintillator assembly.

B. Specifications

Crystal:

For 810B: 810-20 well-crystal photomultiplier assembly for 5 ml samples. Well size $2\frac{1}{32}$ " diameter x $1\frac{35}{64}$ " deep. Crystal size $1\frac{3}{4}$ " diameter x 2" thick.

For 810BL: 810-22 well-crystal photomultiplier assembly for 15 ml samples. Well size 1" diameter x 1-35/64" deep. Crystal size 2" diameter x 2" thick.

For 810BB: 811-7 well plastic scintillator-photomultiplier assembly. Well size 43/64" diameter x 1-7/8" deep. Assembly dimensions 2" diameter x 2-1/4" deep.

For 810BS: 810-20A crystal-photomultiplier assembly. 1-3/4" diameter x 2" thick solid crystal.

Photomultiplier: RCA 6342A

Output:

Amplitude: Max 10V (neg)

Linearity: 1%

Impedance: 50 ohms

Rise Time: 0.5 μ sec

Decay Time: 1.6 μ sec

Shielding: 2" lead

Power Requirements: +200V to +300V at 20 ma,
6.3VAC at 1.2 amps, and
stable H. V. (+500V to +1400V)

Receptacles:

High Voltage MHV(JK-1)

Signal Output BNC(JK-36)

Low Voltage and Signal AN3102A-16S-1S(JK-31)

Cables Supplied: #1 preamplifier cable, #2 high voltage cable

Dimensions: 8-1/2" long x 6-1/2" wide x 11-1/8" high

Net Weight: With 2" lead shield - 80 lbs.

Shipping Weight : With 2" lead shield - 110 lbs.

C. Brief Principle of Operation

The scintillator responds to incident radiation by emitting photons of visible light. These photons are reflected by the housing until they strike the photocathode of the photomultiplier tube, producing photoelectrons which are multiplied within the photomultiplier structure by a factor of up to one million. The resulting voltage pulse is shaped in the preamplifier and amplified by a factor of 10.

II. OPERATING INSTRUCTIONS

NOTE: All references to the Model 810B apply to Models 810BL, 810BB, and 810BS unless otherwise specified.

TABLE II-1
JACKS

Schematic Designation	Type	B/A Part No.	Function
J101, "HV"	MHV	JK-1	Introduces HV for photomultiplier tube
J102, "Signal"	BNC	JK-36	Additional signal jack; not normally used
J103, "Power"	AN	JK-31	Supplies B+ and filament power to 810B and couples signals from 810B to amplifier, etc.

Connections. Connect J101 to a high voltage power supply using the #2 cable supplied. Connect J103 to an amplifier, scaler, or ratemeter using the #1 cable supplied. If using special equipment, be certain that the voltage specifications (listed in Section I-B) are met. J102 provides an additional signal outlet for special purposes.

Operation. There are no controls on the Model 810B. Operating conditions are controlled by other instruments in the system. The B/A "Scintillation Handbook" (available on request) describes the problems to be considered in selecting an operating point.

Figure II-1 illustrates a typical integral curve. Figure II-2 shows a "scintillation plateau."

Counting Efficiency. Since high energy radiation (e.g., gamma rays) is emitted in all directions at random, the fraction which hits the sensitive volume of the detector depends only on the "solid angle" of the crystal, i.e.,

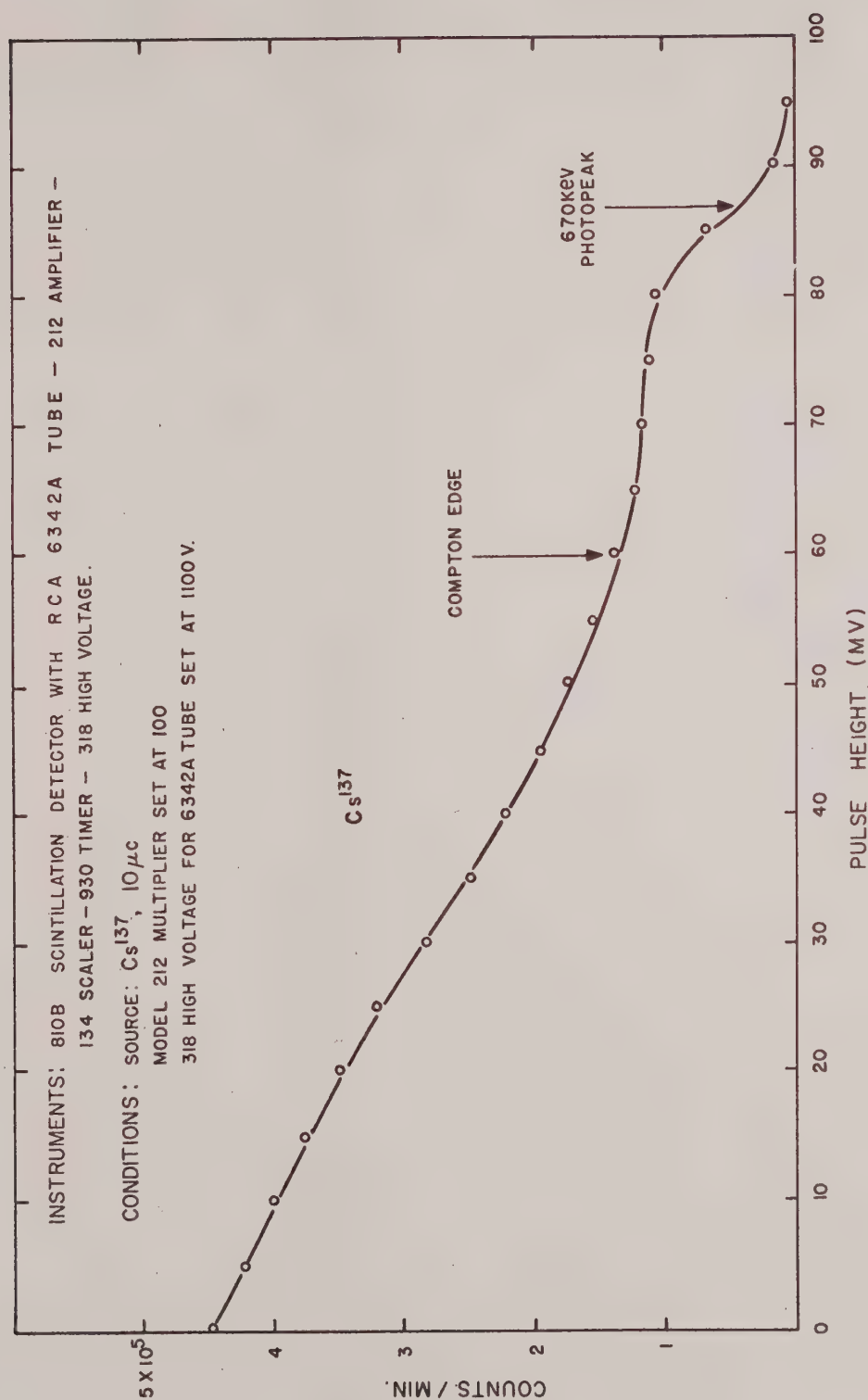


Figure II-1 Typical Integral Curve Using Model 810B

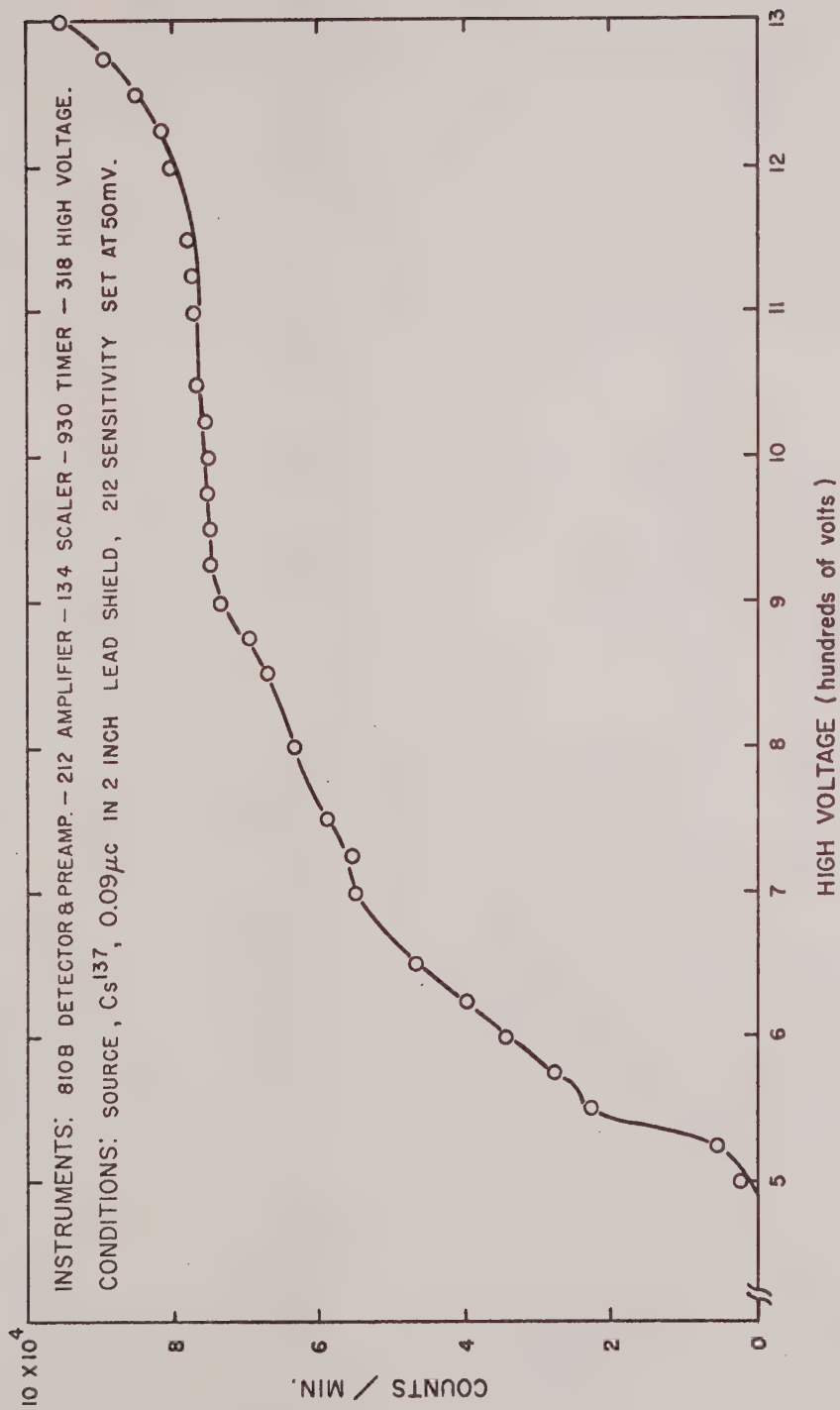


Figure II-2 Typical Scintillation Plateau Using Model 810B

the measure of that portion of the surface of a sphere viewed from the center or source. As Fig. II-3 shows, a well crystal has a much larger solid angle and hence a much greater counting efficiency than a solid crystal. It happens that the size of in vitro medical samples makes it possible to take advantage of this superior counting geometry.

Figure II-3 (right-hand figure) also illustrates the relationship between distance and counting efficiency. At large distances the solid angle decreases as the inverse of the distance squared.

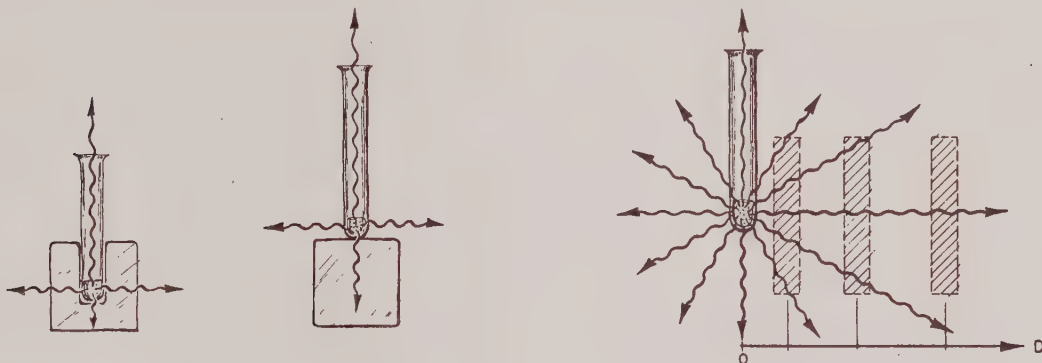


Figure II-3 Solid Angles for Well vs. Solid Crystals

Sample Volume and Counting Efficiency. Because a well is open-ended to permit insertion of the sample, counting efficiency depends upon the position of the sample in the well, as Fig. II-4 shows. The same sample source diluted to a larger volume will be counted less efficiently because more of the gamma rays escape from the open end of the crystal. This decrease in efficiency is virtually linear, as Fig. II-5 shows. That is why the Model 810B well is specified as 5 ml and the Model 810BL well as 15 ml: for larger volumes the counting efficiency drops significantly.

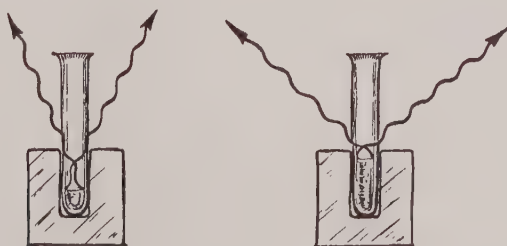


Figure II-4 Relation of Solid Angle to Source Position in Well

Counting Efficiency and Gamma Ray Energy. The counting efficiency of a well counter varies with gamma ray energy. Figure II-6 indicates this relationship for the Model 810B well.

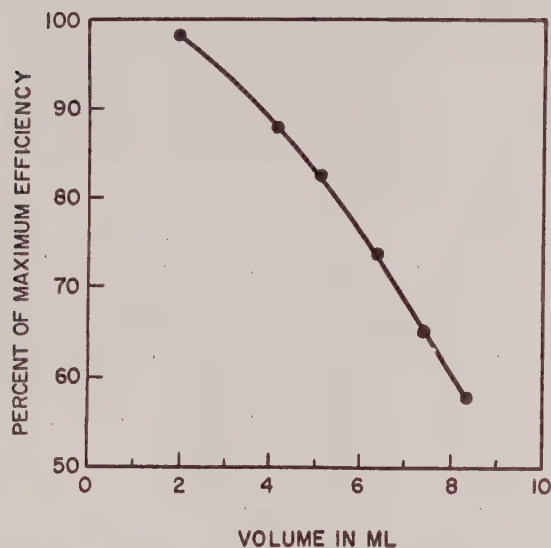


Figure II-5 Relation of Counting Efficiency to Sample Volume in Well

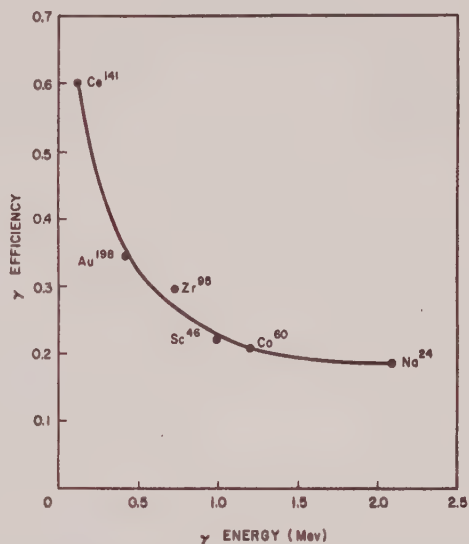


Figure II-6 Relation of Counting Efficiency to Gamma Ray Energy

Since most standard instrumentation introduces some noticeable loss of counts where the counting rate is above a few hundred thousand counts per minute and since the well crystal efficiency for gamma rays is of the order of 10% to 90%, the maximum gamma ray sample activity usually used in the standard well is less than one microcurie.

The lower limit of activity which can be measured in a standard well depends upon the "background" counting rate of the system. Since essentially all materials (even the lead shield) contain some naturally occurring radioactivity and because of ever-present cosmic radiation, a detection system can never be constructed which registers zero counts in the absence of a sample. Thus the average background counting rate which would have been measured without the sample must be subtracted from the total sample counting data to determine the activity due to the sample radioactivity alone.

In the course of an experiment, samples are occasionally encountered which are too active or too inactive to be measured in a standard detection system. Suppose, for example, that routine clinical samples are to be measured in the standard well from patients to whom therapeutic doses of a radioisotope have been administered. Since these samples may have activities of the order of 100 μc , the counting rate capabilities of the standard systems would be exceeded. Two techniques may be used to circumvent this problem. First, the sample may be diluted by a constant factor and small aliquots of the dilution then measured. Second, the sample may be positioned in a rigid support at some distance from the detector. This second technique, of course, uses the inverse square principle mentioned previously to reduce the number of gamma rays incident on the detection crystal.

In some clinical procedures the total sample activity is in the correct range for the standard well system, but the activity is distributed through a very large volume (e.g., urine or slurried stool samples). Again two techniques are commonly used. First, the sample may be concentrated or boiled down to a few ml and then counted in the usual way. Second, and patently more desirable, the sample may be counted in a standard large volume, e.g., one liter. A one liter aliquot of a sample originally larger may be used or a smaller sample diluted to one liter. The large container may be placed directly on the well or a disposable container of special construction may be used (see Fig. II-7).

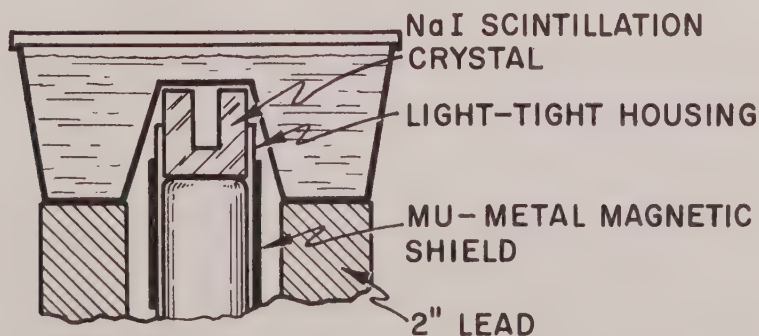


Figure II-7 Special Container for Use with Well Counters

Model 810BB Beta Well. The Model 811-7 Beta Well used in the Model 810BB is a plastic scintillator of very low sensitivity to gamma rays and highly efficient in counting hard betas (greater than 1 Mev). As Fig. II-8 illustrates, this detector, unlike the NaI (Tl) crystals, is non-linear in its response. This makes possible something approaching plateau counting. At the operating level shown, a counting efficiency of 12.2% for P^{32} was obtained.

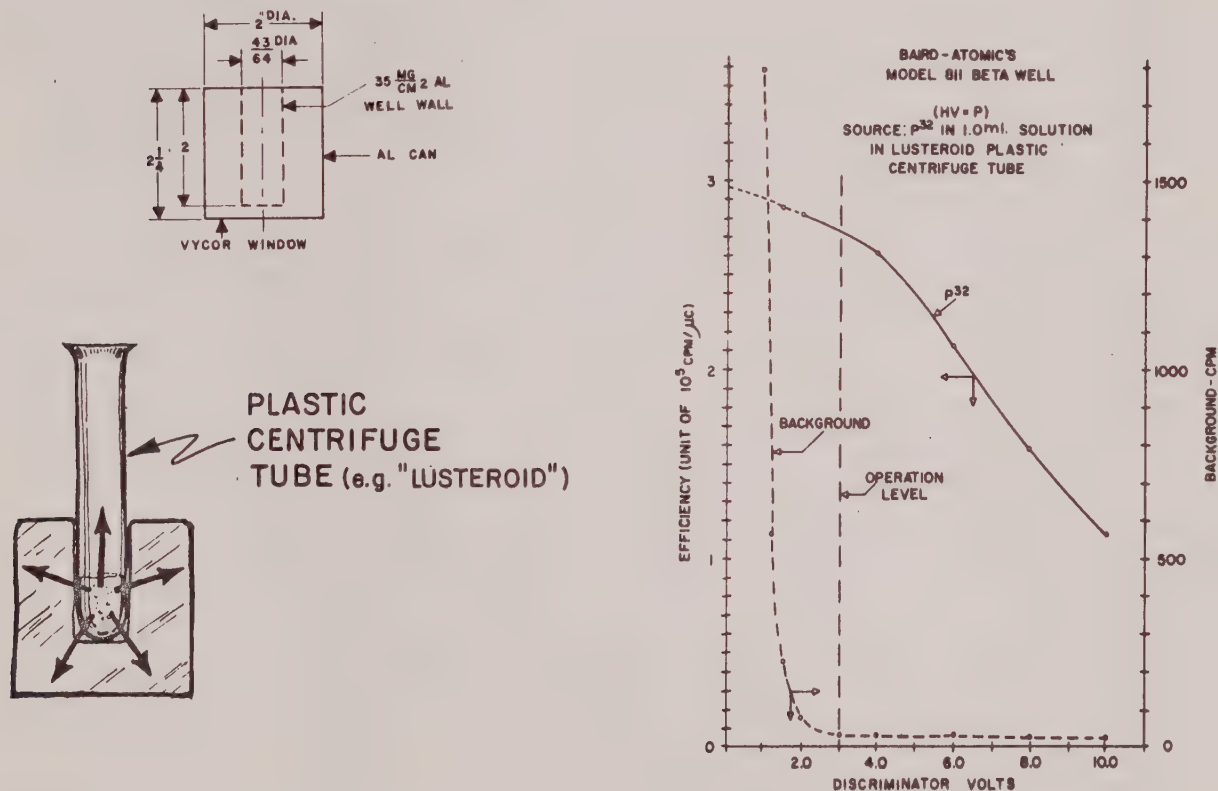


Figure II-8 Various Data on "Beta Well"

The Model 810BB is especially useful in counting β rays in the presence of gammas. For example, consider the problem of counting K^{42} in the presence of Na^{24} :

<u>Beta</u>	<u>Gamma</u>
K^{42} 3.58 Mev (75%); 1.98 Mev (25%)	1.51 Mev (25%)
Na^{24} 1.39 Mev (100%)	1.38 Mev (100%);
	2.75 Mev (100%).

It is easy enough to count sodium in the presence of potassium by absorbing the beta rays and attenuating the weak potassium gamma rays. To count potassium in such a mixture, one must discriminate against the gamma rays and absorb the weak sodium beta ray. Model 811-7 Beta Well will easily perform this kind of counting. It is built of materials of low atomic number and low density to reduce high-energy gamma interactions. Its small sensitive volume reduces the number of gamma interactions. The well geometry has been optimized and thin well walls (0.005" of Al) are used to minimize absorption. Plastic test tubes with their lower stopping power ought to be used when possible in this type of work, but if glass test tubes must be used, be certain that they are of the thin-wall variety.

Note that the aluminum wall of the 811-7 wells is extremely thin and fragile. Therefore when inserting samples and changing phototube-well assemblies, handle with care.

Model 810BS. As a glance at Fig. III-1 will reveal, much of the sensitive area of the solid crystal is blocked by the top portion of the shield. Usually this particular model is purchased for some special application and the shield individually modified by the owner for this purpose. The top section of the shield can be removed quite easily by unscrewing the two top screws.

III. MECHANICAL AND ELECTRONIC DETAILS

A. Construction

Figure III-1 is a cross-section of the Model 810B. A lead shield surrounds the crystal-photomultiplier assembly on all sides; the top plate of the shield is removable. The photomultiplier is additionally sheathed in a magnetic shield made of "Mu-metal." The preamplifier electronics is housed in the base of the instrument. The crystal-photomultiplier assembly is removable from the top by inserting a finger into the well after the cover is removed and carefully rocking the assembly loose.

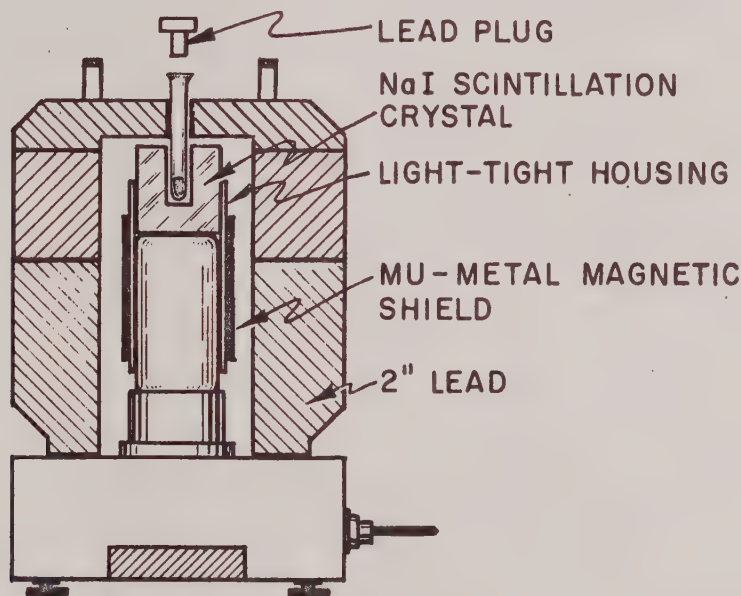


Figure III-1 Cross-Section of Model 810B

This manual will not presume to cover in any detail the mechanism of scintillation of the NaI (Tl) crystal* or the design principles of the photomultiplier tube. Scintillation counting depends on the ability of a phosphor (or a plastic, liquid etc.) to convert into photons of light some fraction of the energy lost by ionization during the passage of a charged particle or of gamma ray photons through the crystalline material. The cathode of the

*See Birks, J. B., Scintillation Counters, McGraw-Hill, 1953.

RCA 6342A phototube is sensitive to illumination over the 3000-6500 angstrom (peak 4400) range which is emitted by thallium-activated sodium iodide crystals. The phototube cathode on which the photons of light impinge responds by emitting secondary electrons which are directed by fixed electrostatic fields to the first dynode, producing a number of electrons dependent on the energy of the impinging electrons. The secondary electrons are then directed by fixed electrostatic fields along curved paths to the second dynode where they produce more new electrons. This multiplying process is repeated in each successive stage with an ever-increasing stream of electrons until those emitted from the last dynode (#10) are collected by the anode and constitute the current utilized in the output circuit. The amplification factor is on the order of 10^6 .

B. Electronics

High voltage is applied to the photomultiplier through the resistive divider consisting of R114, 102, 103-113. C102, R133, and C101 constitute a high voltage filter network. C103 is a high voltage blocking condenser.

Negative pulses from the photomultiplier are differentiated by R101 and the stray capacitance and applied through C103 to the grid of V102A. These are amplified by V102A and coupled through the cathode to V102B, another stage of amplification. Negative signals at the plate of V102B are coupled through C105 to V103A. Amplified positive pulses at the plate are coupled through C106 to the grid of V103B while negative pulses are coupled to the cathode of V103B, thus increasing the signal swing. Negative pulses at the plate of V103B are fed back to the grid of V102B where, being of the same polarity as the pulses on the cathode, they act as negative feedback. The gain of the amplifier, V102 and 103, is 40. This is reduced by a factor of four by R137 and R125, giving an output with a gain of 10. This permits V102 and 103 to operate in a region of optimum signal-to-noise ratio with the output amplitude being subsequently cut. Pulses from the plate of V103B are also fed to V104,

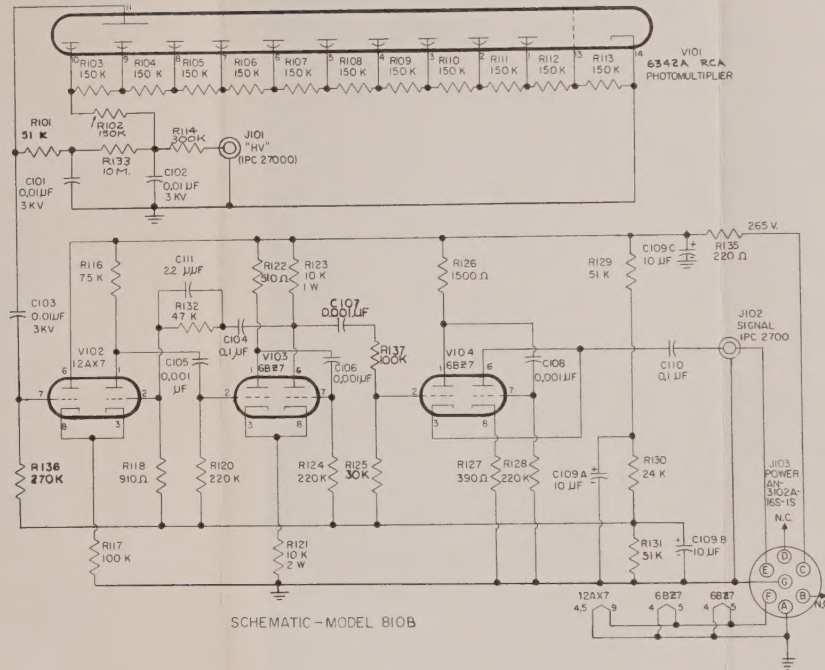
the output stage, a stacked cathode follower. In this circuit, the output taken from the cathode of V104A follows the phase of the grid signals and produces an output with a gain close to one. The inverted signal at the plate of V104A is fed to the grid of V104B. Therefore, the larger the input signal, the lower the impedance of the cathode circuit, and the greater the high frequency response. The output is negative, differentiated signals. R129, 130, and 131 are a divider string for the bias voltage, further filtered by C109A and B.

IV. PARTS LIST

Schematic Designation	Description	B/A Designation
R101	51K, 1/2 W, 5%, comp.	RCE513J
102	150K, 1/2 W, 5%, comp.	RCE154J
103	150K, 1/2W, 5%, comp.	RCE154J
104	150K, 1/2W, 5%, comp.	RCE154J
105	150K, 1/2W, 5%, comp.	RCE154J
106	150K, 1/2W, 5%, comp.	RCE154J
107	150K, 1/2W, 5%, comp.	RCE154J
108	150K, 1/2W, 5%, comp.	RCE154J
109	150K, 1/2W, 5%, comp.	RCE154J
110	150K, 1/2W, 5%, comp.	RCE154J
111	150K, 1/2W, 5%, comp.	RCE154J
112	150K, 1/2W, 5%, comp.	RCE154J
113	150K, 1/2W, 5%, comp.	RCE154J
114	300K, 1/2W, 5%, comp.	RCE304J
115	Omitted	
116	75K, 1/2W, 5%, comp.	RCE753J
117	100K, 1/2W, 5%, comp.	RCE104J
118	910 Ω , 1/2W, 5%, comp.	RCE511J
119	Omitted	
120	220K, 1/2W, 5%, comp.	RCE224J
121	10K, 2W, 5%, comp.	RCH103J
122	510 Ω , 1/2W, 5%, comp.	RCE511J
123	10K, 1W, 5%, comp.	RCG103J
124	220K, 1/2W, 5%, comp.	RCE224J
125	30K, 1/2W, 5%, comp.	RCE303J
126	1.5K, 1/2W, 5%, comp.	RCE152J

Schematic Designation	Description	B/A Designation
R127	390 Ω , 1/2W, 5%, comp.	RCE391J
128	220K, 1/2W, 5%, comp.	RCE224J
129	51K, 1/2W, 5%, comp.	RCE513J
130	24K, 1/2W, 5%, comp.	RCE243J
131	51K, 1/2W, 5%, comp.	RCE513J
132	47K, 1/2W, 5%, comp.	RCE473J
133	10 meg, 1/2W, 5%, comp.	RCE106J
134	Omitted	
135	220 Ω , 1/2W, 5%, comp.	RCE221J
136	270K, 1/2W, 5%, comp.	RCE274J
137	100K, 1/2W, 5%, comp.	RCE104J
C101	.01 μ f, 3KV, mylar	CP103-6
102	.01 μ f, 3KV, mylar	CP103-6
103	.01 μ f, 3KV, mylar	CP103-6
104	0.1 μ f, 200V, mylar (Goodall)	CP104-10
105	.001 μ f, ceramic disc, 500V	CC102-1
106	.001 μ f, ceramic disc, 500V	CC102-1
107	.001 μ f, ceramic disc, 500V	CC102-1
108	.001 μ f, ceramic disc, 500V	CC102-1
109A,B,C	10/10/10 μ f, 350V, electrolytic (Mallory FP330-5)	CE106-4
110	0.1 μ f, 200V, mylar (Goodall)	CP104-10
111	22 μ f, tubular	CC220-3
V101	RCA 6342A Photomultiplier	6342A
102	12AX7	12AX7
103	6BZ7	6BZ7
104	6BZ7	6BZ7

Schematic Designation	Description	B/A Designation
J101	MHV (1PC 27000)	JK-1
102	BNC (1PC 2700)	JK-36
103	7-pin connector (AN3102A-16S-1S)	JK-31



SCHEMATIC
SCINTILLATION HEAD & PREAMP
MODEL 810 B

810B-1

C

WARRANTY

Baird-Atomic, Inc. (the "Company"), warrants this equipment for a period of 1 year from the date of shipment as follows: it warrants that all equipment of its manufacture is free from defects in material and workmanship at the time of shipment. If within 1 year of shipment any equipment of the Company's manufacture develops defects in material or workmanship under normal conditions of operation, the buyer of the equipment may return it to the Company within 30 days of such failure, for repairs at the expense of the Company, including the expense of shipment, or in the case of any defective part may return such part to the Company which will repair or replace the same at its expense, including the cost of shipment. A further warranty of 1 year on the same terms shall be applicable to any part so repaired or replaced. Except for Dekatron glow tubes, this warranty does not extend to stock components not manufactured by the Company.

The Company shall not be liable for damage or destruction of instruments during delivery or caused by other than employees of Baird-Atomic, Inc.; in any event, liability shall not exceed the cost of replacement of defective parts upon prompt notification of such defect.

For return of equipment or any part thereof under the terms of the foregoing warranty a letter should be forwarded to Baird-Atomic, Inc., Attention: Sales Service Department, 33 University Road, Cambridge 38, Massachusetts. It should state owner's name and address; model and serial number of the equipment; the order number, under which it was purchased; the date of failure and a description of the circumstances surrounding same. Upon receipt of such information, shipping instructions for return of equipment or parts thereof will be forwarded promptly.

Baird-Atomic, Inc.

33 UNIVERSITY RD., CAMBRIDGE 38, MASS.

